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Sachidananda Muni
Department of Chemistry, College of Basic Science and Humanities, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Corresponding Author:
Sachidananda Muni
Department of Chemistry, College of Basic Science and Humanities, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Effect of the application of alkaline FA in conjunction with NPK fertilizers and FYM on physico chemical properties of acidic soil

Sachidananda Muni

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Abstract
A field experiment was carried out in the year 2022 in Kharif season to study the effect of application of alkaline fly ash (FA) in conjunction with NPK fertilizers and farm yard manure (FYM) on the physico - chemical properties of soil. The crop grown was rice cv. Pooja. It was observed that the porosity increased in all the treatments and the highest value was 53.58% in the plot receiving 50% RD + 40t FA ha^{-1} + 10t FYM ha^{-1}. Bulk density decreased with higher doses of fly ash and was lowest in the plot receiving 50% RD + 40t FA ha^{-1} + 10t FYM ha^{-1}. Water holding capacity increased in all the treatments except the one receiving only NPK fertilizers (control). It increased with increase in the dose of fly ash and registered highest values in FYM treated plots. pH also registered higher values all the treatments and increased with the dose of fly ash. Electrical conductivity and organic carbon increased in all the treatments over the experimental soil and recorded highest values in the FYM treated soil. The macro nutrients N, P and K also increased over the experimental soil and registered highest values in the FYM treated soil with higher dose of fly ash.

Keywords: Fly ash, NPK fertilizers, farmyard manure, soil properties, rice cultivation

Introduction
Fly ash is an obnoxious waste materials produced from coal based thermal power plants. This obnoxious solid waste has been causing environmental problems all over the world. It is produced is huge quantities in our country. It is used in manufacturing of bricks, cements and other civil construction activities. But its utilization is limited. However most of the FA produced in India including in the state of Odisha are alkaline in nature and thus fit well to acid soils as an amending agent. FA has many other physical and chemical characteristics such as porosity, bulk density, water holding capacity and nutrient constituents which can enhance the soil quality which may aid in the uptake of nutrients and hence the quality of grains would be better.

Out of the total ice-free land area of the world, approximately 30% or 3950 m.ha comes under acid soil. Asia, as a continent has the second largest area of such soil which is about 1044 m.ha. However, only 4.5% (179 m.ha) of area of the acid soil in the world has been used for arable crops. In India, acid soils comprise about 28% of the total geographical area (TGA), out of which 9.3% are strong to moderately acidic (pH < 5.5) while 18.9% are slightly acidic (pH 5.5 to 6.5). These soils are distributed in the Himalayan region, the eastern and the north - eastern plains, peninsular India and the coastal plains under varying agro - climatic conditions. Such soils occupy about 90Mha of the TGA, out of which 50% is under cultivation and the rest is under forestry and other uses. About 30Mha of cultivated land with pH less than 5.5 is critically degraded with major soil - related constraints leading to poor crop production. The degraded area in Chhattisgarh and Arunachal Pradesh is predominantly under forests. About 21 Mha of acid soils are found in the North - eastern hill (NEH) region including Sikkim.

Farmers apply FYM along with various types of fertilizers in soil to grow crops. There is a need to evaluate the effect of the combination of FA and NPK fertilizers with and without FYM on the soil health after the harvest of crop.

Materials and Methods

A field experiment was carried out to study the effect of application of different treatments consisting of alkaline FA in conjunction with NPK fertilizers and FYM on the nutrient uptake by rice cv. Pooja. After harvest the physico - chemical properties of soil were determined. The field of study was Regional Research and Technology Transfer Station (RRTTS), Odisha University of Agriculture and Technology, Bhubaneswar, India taking nine numbers of different treatments in 5m × 3m plots replicated thrice in a randomized block design. Both of those were given nine treatments consisting of various doses of FA, nitrogen, phosphorous, potassium (NPK) fertilizer and FYM with only NPK serving as the control as per Pradhan, 2002. The treatments were: (1) RD of 80,40, 40 kg N, P, K ha^{-1} (2) 20 t FA ha^{-1} (3) 40 t FA ha^{-1} (4) RD + 20 t FA ha^{-1} (5) RD + 40 t FA ha^{-1} (6) 50% RD + 20 t FA ha^{-1} (7) 50% RD+ 20 t FA ha^{-1} (8) 50% RD + 20 t FA ha^{-1} + 10 t FYM ha^{-1} (9) 50% RD + 40 t FA ha^{-1} + 10 t FYM ha^{-1}. The RD with neither FA nor FYM served as the control. The physical properties were examined before transplanting and after harvest.

The mechanical analysis was done by Bouyoucos Hydrometer method as described by Piper, C.S. (1950). The pH and EC was determined by taking 1: 2 soil: water suspension. The organic carbon (O.C) and available P was determined by Walkley and Black method as described by Jackson M.L. (1967). Available K was extracted by 1N Ammonium Acetate (pH 7.0) abd estimated by flame photometer). N was determined by Alkaline Potassium Permanganate method as described by.

Results and Discussion

The soil of the experimental site at the Regional Research and Technology Transfer Station (R.R.T.T.S), Odisha University of Agriculture and Technology, Bhubaneswar was lateritic silty loam having acidic pH of 5.32, electrical conductivity of 0.31dSm^{-1}, medium O.C content of 0.53%, available N, P and K content were 370.0, 19.6 and 166.8 $kgha^{-1}$ respectively. It has cation exchange capacity (CEC) of 8.65 cmol (P^{+}) kg^{-1} and available micronutrients were above the critical limit. The available sulphur was however low. The properties of the experimental soil are given in Table - 1

The FA used for the experiment collected from ICCL, Chowdwar, Odisha was alkaline in nature (pH = 7.30) and had low bulk density (BD) (0.847 Mgm^{-3}) with 89.6% WHC and 41.0% porosity. It also contained 30.0 $mgkg^{-1}$ P, 180.0 $mgkg^{-1}$ K and 180.3 $mgkg^{-1}$ S. Besides, it was also rich in many important micronutrients like Zn, Cu and B which were low in the experimental soil but had beneficial effect on soil health. The properties of the FA are recorded in Table - 2.

Table-1: Properties of the experimental Soil

Category	Property	Value
Physical Properties	Porosity (%)	39.0
	Bulk Density (Mgm-3)	1.42
	WHC (%)	34.11
	CEC [cmol(P+)kg-1]	8.65
	Sand (%)	54.0
	Silt (%)	29.4
	Clay (%)	16.6
	Texture	Silty Loam
Chemical Properties	pH (1:2)	5.32
	EC (dSm-1)	0.31
	O.C (%)	0.53
Macronutrients	Available N (kgha-1)	370.0
	Available P (kgha-1)	19.6
	Available K (kgha-1)	166.8
	Ca (cmol(P+)/kg)	5.05
	S (mgkg-1)	6.52
Micronutrients	Fe (mgkg-1)	71.0
	Mn (mgkg-1)	30.6
	Zn (mgkg-1)	0.80
	Cu (mgkg-1)	0.54
	Ni (mgkg-1)	0.86
	B (mgkg-1)	0.72
Heavy Metal	Cd (mgkg-1)	0.008

Table 2: Properties of FA

Category	Property	Value
Physical Properties	Porosity (%)	41.0
	Bulk Density (Mgm-3)	0.847
	WHC (%)	89.6
Chemical Properties	pH (1:2)	7.30
	EC (dSm-1)	0.73
	O.C (%)	0.30
	N (mgkg-1)	5.0
	P (mgkg-1)	30.0
	K (mgkg-1)	180.0
	Ca (mgkg-1)	900.0
	S (mgkg-1)	180.3
	Fe (mgkg-1)	9.46
	Mn (mgkg-1)	0.80
	Zn (mgkg-1)	9.46
	Cu (mgkg-1)	2.16
	Ni (mgkg-1)	1.98
	B (mgkg-1)	0.90
Heavy Metal	Cd (mgkg-1)	0.25

The physical properties of the soil were examined after the harvest of cv. Pooja in 2022 in order to determine the residual effects of FA, FYM and their combinations with N, P, and K on it. The results of the physical properties has been given in Table - 3 and shown in Fig - 1.

Porosity

Porosity is the air space between soil particles, which is occupied by water when available. Perusal of the data from table - 3 revealed that the porosity of the soil varied between the lowest of 46.06% in T_1 receiving 100% RD of N, P and K fertilizer (control) and the highest of 53.58% in T_9 receiving 50% RD of NPK integrated with FA @ 40tha^{-1} and FYM @ 10tha^{-1}. When FA @ 20tha^{-1} was added, there was an increase by 7.05% and when the dose of FA was doubled there was further increment of 4.78%. On an average, treatments receiving FA recorded an increase in porosity by 9.61% over control. It might be due to the presence of Ca present in FA (900ppm) that readily replaces Na at clay exchange sites and thereby enhances flocculation of soil clay particles, keeps the soils friable, enhances water penetration and allows roots to penetrate compact soil layers [1]. Treatments receiving 100% RD of NPK fertilizer integrated with FA recorded a significant increase by 4.40% over FA and 14.43% over 100% RD of NPK. However, when the dose of fertilizer was reduced to 50% there was a fall by 0.13%. But, when FYM was included in the doses (T_8 and T_9) there was an increment by 1.42% over the treatments receiving same dose of other nutrients except FYM. On an average, treatments receiving FA @ 40tha^{-1} registered 1.85% more porosity of soil than the treatments receiving FA @ 20tha^{-1}. The higher porosity was however, recorded in the treatments receiving FYM which 15.91% higher than control. Except T_2 receiving FA @ 20tha^{-1}, all other treatments recorded a significant increase over control. Higher porosity in FYM amended treatments might be due to the increased microbial activity. The application of organic manures resulted in the increased organic matter in soil and hence the porosity of soil [2].

Table-3: Physical properties of the soil after the harvest of cv. Pooja (Kharif)

Treatment No	Porosity (%)	B.D (Mgm^{-3})	WHC (%)
T_1	46.06	1.43	31.20
T_2	49.31	1.34	33.83
T_3	51.67	1.28	38.50
T_4	52.35	1.29	37.34
T_5	53.07	1.27	39.31
T_6	52.46	1.26	36.25
T_7	52.82	1.25	38.11
T_8	53.20	1.24	39.49
T_9	53.58	1.23	41.54
SE (±m)	0.04	0.01	0.14
CD (0.05)	0.12	0.03	0.43

Bulk Density

The BD of soil varied between the lowest of 1.23 Mgm^{-3} in T_9 receiving 50% RD of NPK fertilizer integrated with FA @ 40tha^{-1} and FYM @ 10tha^{-1} and the highest of 1.43Mgm^{-3} in T_1 (control) receiving only 100% RD of NPK fertilizer. It decreased significantly by 6.29% to 1.34Mgm^{-3} with FA @ 20tha^{-1} and by 10.49% to 1.28Mgm^{-3} when the dose of FA was doubled over control. It might be due to the fact that the particle size of FA is similar to silt having low specific gravity that decreased the BD of soil. Application of FA @ 0%, 5%, 10% and 15% by weight in soil significantly reduced the BD of soil [3]. T_3 receiving FA @ 40tha^{-1} was at par with the treatments receiving 100% RD of NPK fertilizer integrated with FA. When the RD of fertilizer was reduced to 50% there was no significant decrease in BD of soil. It further reduced by 1.59% when FYM was added. It is because of the combined effect of inorganic fertilizer and FA with FYM since FYM is also low in BD [4]. FYM treated plots registered lower values among all the treatments. On an average, there was an increment by 1.95% when the dose of FA was increased from 50% to 100%.

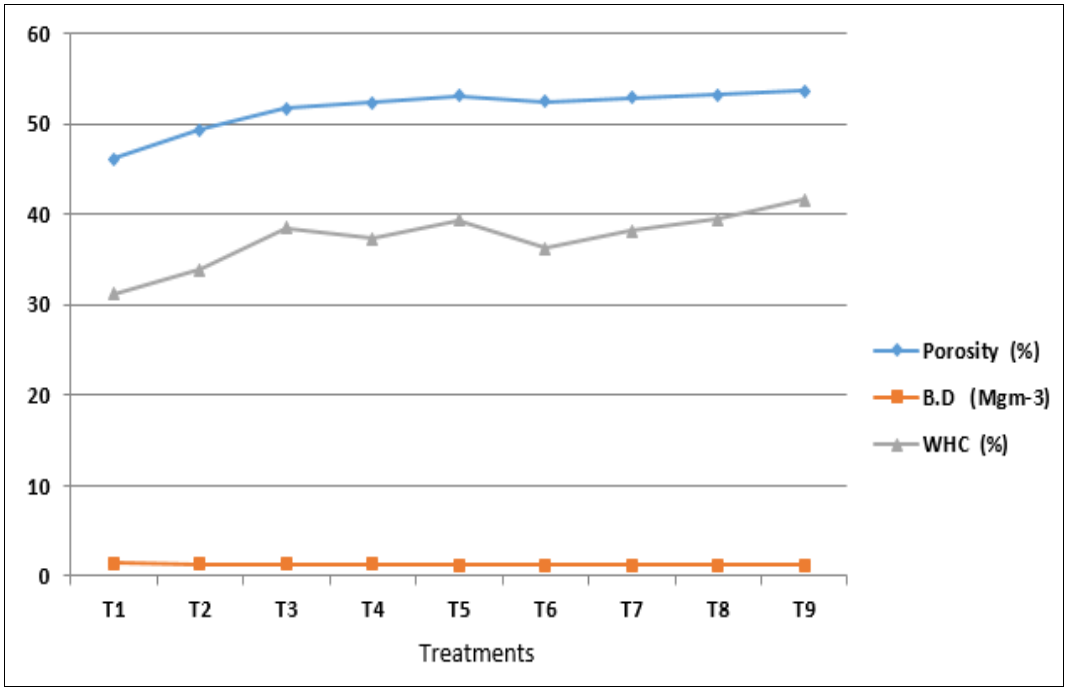

Fig 1: Physical Properties after harvest

Water Holding Capacity (WHC)

WHC of soil varied between the lowest of 31.2% in T_1 (control) receiving 100% RD of fertilizer and the highest of 41.54% in T_9 receiving 50% RD of NPK fertilizer integrated with FA @ 40tha^{-1} and FYM @ 10tha^{-1} (Figure 4.3.1.3). On application of FA @ 20tha^{-1} and 40tha^{-1} respectively, WHC registered an increase by 8.43% and 23.40% respectively over control receiving only 100% RD of FA. On an average, application of FA registered an increase in WHC by 15.91% over control. Amendment with FA up to 40% increased WHC of soil from 39% to 55% [5]. It might be due to the fact that FA application to soil increases microporosity, decreases bulk density and thereby improves the WHC. When FA was blended with 100% RD of NPK fertilizer there was a further increase by 5.97% over FA and significant increase by 22.83% over control. However, when there was a reduction of RD of fertilizer by 50%, there was a fall by 2.99%. But when FYM was incorporated in the treatments, there was an increase by 8.95% over the treatments receiving no FYM. There was an increase by 29.83% in FYM treated plots over control receiving no FA and fertilizer. On an average there was an increase by 7.18% when the dose of FA increased.

The chemical properties and macro nutrients of the soil were examined after the harvest of cv. Pooja in order to determine the residual effects of FA, FYM and their combinations with N, P, and K on it. The result has been given in Table - 4 and shown in Fig 2 and 3 respectively.

Table 4: Chemical properties and macro nutrients of soil after harvest

Tr.No	pH	EC (dSm^{-1})	OC (%)	N (kgha^{-1})	P (kgha^{-1})	K (kgha^{-1})
T_1	5.45	0.41	0.54	468.14	23.04	200.98
T_2	5.53	0.45	0.50	458.11	21.00	195.78
T_3	5.94	0.44	0.52	461.13	21.15	197.81
T_4	5.49	0.46	0.54	471.11	23.91	201.34
T_5	5.60	0.48	0.56	473.23	24.03	204.81
T_6	5.69	0.45	0.52	465.31	22.26	200.49
T_7	5.96	0.45	0.53	470.12	23.99	204.78
T_8	6.01	0.51	0.62	494.34	29.15	210.33
T_9	6.04	0.53	0.64	499.81	30.11	217.57
SE (±m)	0.11	0.04	0.01	0.12	0.07	0.14
CD (0.05)	0.32	0.11	0.02	0.34	0.20	0.41

pH

The pH of the soil varied from the lowest of 5.45 in T_1 receiving RD of NPK fertilizer to the highest of 6.04 in T_9 receiving 50% RD of fertilizer integrated with FA @ 40tha^{-1} and FYM @ 10tha^{-1}. With FA @ 20tha^{-1} and 40tha^{-1} there was an increase of 1.46% and 9.0% respectively over control. This might be due to the presence of alkaline hydroxide and carbonate salts of Ca, Na and Al present in FA which helps in neutralizing the acidity in soil[6] [15]. But when full dose of NPK fertilizer was integrated with FA, there was a fall in pH by 3.31% over FA but registered an increase by 1.74% over 100% RD of fertilizer (control). It might be because combined effect of fertilizer and FA could not lime the soil effectively as compared to FA. However, when the RD of fertilizer was reduced to half, there was an increment by 5.05%. On an average, when FYM was included in the treatments, there was an increase by 3.43% over its exclusion. It might be due to the addition of basic cations through application of organic materials [7]. On an average, there was an increase of 3.61% in treatments receiving 40tha^{-1} FA over its lower dose.

Electrical conductivity (EC)

The electrical conductivity of the soil varied from the lowest of 0.41 dSm^{-1} in control plot 100% receiving RD of fertilizer to the highest of 0.53dSm^{-1} in T_9 receiving 50% RD of fertilizer integrated with FA @ 40tha^{-1} and FYM @ 10tha^{-1}. With FA@ 20tha^{-1} and 40tha^{-1}, there was an increase by 9.75% and 2.22% respectively over control. Increase in the EC value of soil due to the addition of FA may be attributed to the fact that the soluble salts from FA might have dissolved in soil moisture and there by increased the ionic concentration of the soil solution[8] [39]. When 100% RD of fertilizer was integrated with FA, there was a further increase by 5.62% over FA and 14.63% over control. But, when the dose of fertilizer was reduced to 50%, there was a reduction by 3.19%. However, when FYM was included in the doses, there was a significant increase by 14.28% over the treatments receiving same doses of fertilizers except FYM. On an average, treatments receiving FA @ 40tha^{-1} increased the EC of soil by 2.13% over 20tha^{-1}.

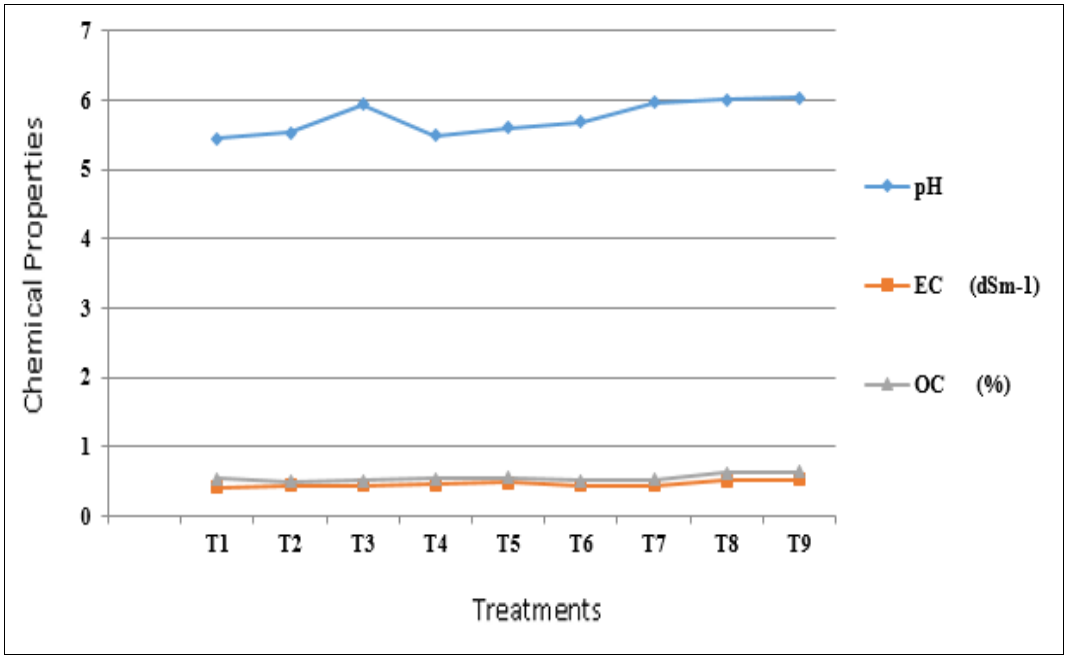

Fig 2: Chemical properties after harvest

Organic Carbon (OC): The OC content of the soil varied from the lowest of 0.50% in T_2 receiving FA @ 20tha^{-1} to the highest of 0.64% in T_9 receiving 50% RD of fertilizer integrated with FA @ 40tha^{-1} and FYM. When 100% RD of fertilizer was replaced by FA @ 20tha^{-1} and 40tha^{-1}, there was a decrease by 7.40% and 3.70% respectively. Increase in the dose of FA resulted in the increase of the organic matter content in acid soil [8]. When 100% RD of fertilizer was integrated with FA, there was an increase by 7.84% over FA and 1.85% over control. However, when the dose of fertilizer was reduced to 50%, there was a fall by 4.54%. With integrated use of 50% RD of NPK with FA and FYM, there was significant increase by 20% and recorded higher values among all the treatments. This proved that the integrated use of FYM and FA with reduced dose of fertilizer built up more organic carbon. It might be due to the fact that FYM contains considerable amount of organic matter [8]. On an average, there was a hike in carbon content by 3.12% in treatments receiving 40tha^{-1} FA over 20tha^{-1} FA.

Available Nitrogen (N): The residual available nitrogen content of the soil varied from the lowest value of 458.11 $kgha^{-1}$ in T_2 receiving FA @ 20tha^{-1} and 499.81$kgha^{-1}$ in T_9 receiving 50% RD integrated with FYM and FA @ 40tha^{-1}. It was observed that on an average there was a significant fall in the available nitrogen status by 1.82% over control by the application of FA. It is because FA contains very less quantity of the element as most of it is lost during the combustion of coal. However, when the dose of FA was doubled as in T_3 there was significant increase by 0.66%. When 100% RD of fertilizer was integrated with FA, on an average there was an increment by 2.73% over FA and 0.86% over control plot. It is because 100% RD of fertilizer contains more nitrogen. However, when the dose of fertilizer was reduced to half, there was a fall by 0.94%. When FYM was included in the treatments, there was an increase by 6.27% over the treatments receiving same dose of nutrients except FYM and 6.17% over control. They had even significantly higher values than integrated use of 100% RD of NPK and FA (T_4 and T_5). This proved that the reduction of the dose of fertilizer had been compensated by the application of FYM. This might be because FYM augmented the mobilization of soil nitrogen [9].

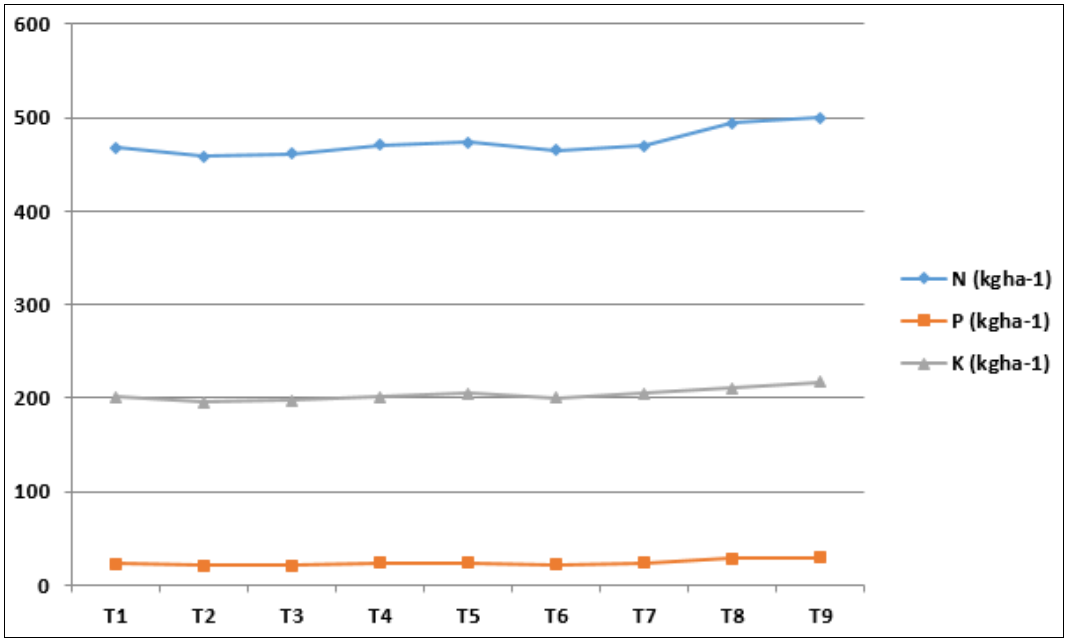

Fig 3: Macro nutrients after harvest

Available Phosphorous (P)

The amount of available P varied between the lowest of 21.00kgha^{-1} in T_2 receiving FA @ 20tha^{-1} to the highest of 30.11kgha^{-1} in T_9 receiving 50% RD integrated with FYM and FA @ 40tha^{-1}. Application of FA @ 20tha^{-1} registered a fall by 9.71%. This is because FA contains less quantity of phosphorous. However, when the dose of FA was doubled there was an elevation by 0.71%. This might be due to the desorption of some native soil P by anions such as silicate, citrate and tartarate from colloidal surfaces by the high addition of FA [10]. When 100% RD of NPK fertilizer along with FA was applied, there was an increase by 13.77% over FA and 4.03% over 100% RD of NPK. This is due to the supply of more P through NPK fertilizer. But when the dose of NPK fertilizer was reduced by 50%, there was a fall by 3.55%. However, when FYM was included in the treatments there was a significant increase by 28.16%. This is due to the increase in soil pH in those plots that reduced the fixation of available P [11]. This proved that the reduction of the dose of fertilizer by 50% had been counter balanced by the inclusion of FYM since FYM mobilized the availability of P in acid soil. There was an increase by 28.60% in FYM treated plots over control. On an average, there was an increase by 3.07% with the application of higher dose of FA over its lower dose.

Available Potassium (K)

Available K varied from the lowest of 195.78 kgha^{-1} in T_2 receiving FA @ 20tha^{-1} to the highest of 217.57 kgha^{-1} in T_9 receiving 50% RD integrated with FYM and FA @ 40tha^{-1}. Application of FA @ 20tha^{-1} registered a decrease by 2.58% over control. But when the dose of FA was doubled, there was a hike by 1.03%. On increasing the dose of FA, there was an increase of K content of soil [8]. On an average, when only FA was applied, there was a fall by 2.08% over control. There was a fall of K content by the application of FA over chemical fertilizers. When 100% RD of fertilizer blended with FA was included in the treatments, there was a hike by 3.18% over FA and 1.04% over control. But, when the dose of fertilizer was reduced to 50%, there was a fall by 0.70%. However, when FYM was included in the treatments, there was a significant increase by 6.11% over the treatments receiving no FYM but all other same nutrients and 6.45% over control. This is due to the increase in soil pH that reduced the fixation of available K [11]. This proved that the reduction of the dose of fertilizer had been compensated by the combined effect of FA and FYM since FYM mobilized the K release. Similar trend of increase in available K content of soil was also reported [12]. On an average, treatments receiving 40tha^{-1} FA recorded an increase in available K by 1.86% over 20tha^{-1}.

Summary and Conclusion

Physical Properties

Application of fly ash at either dose registered significantly higher porosity and WHC but lower BD of soil than 100% RD of NPK (control). Treatments receiving higher dose of FA registered higher values of porosity and WHC but lower BD. Integration of 100% RD of NPK with FA significantly increased the porosity and WHC but decreased the bulk density over FA and control. All the physical properties reduced with the reduction in the dose of fertilizer. Treatments receiving FYM recorded significantly higher values of porosity and WHC but lower BD than its exclusion. FYM treated plots had comparable values of porosity and WHC with integration of 100% RD of NPK with FA (T_4 and T_5).

Chemical Properties

pH

Application of FA was statistically at par with 100% RD of NPK (control) in influencing the pH of soil. However, treatments receiving higher dose of FA recorded higher pH. Integration of FA with 100% RD of NPK registered an insignificant fall over FA but insignificant increase over control. Reduction in the dose of fertilizer slightly increased the pH. Among all the treatments FYM treated plots registered higher values.

Electrical Conductivity (E.C)

Application of lone FA registered significantly higher value of E.C than 100% RD of NPK (control). Higher dose of FA recorded higher values. Integration of FA with 100% RD of NPK recorded higher value than both lone FA and 100% RD of

NPK. Reduction in the dose of NPK had no effect on E.C. Integration of FYM recorded significantly higher values over its exclusion and control. Combination of FYM with 50% RD of NPK and FA had even higher E.C values than integration of 100% RD of NPK and FA (T_4 and T_5).

Organic Carbon (O.C)

The soil OC was significantly less with application of FA at either dose than 100% RD of NPK (control). However, treatments receiving increased dose of FA recorded higher values. Integration of FA at either dose with 100% RD of NPK recorded significantly higher values over FA but was statistically at par with 100% RD of NPK. It decreased with the reduction in the dose of fertilizer. Higher content of OC among all the treatments was maintained by the integrated use of FYM with fertilizer and FA at either dose.

Primary elements (N, P and K)

Application of FA resulted significantly lower values of available N, P and K content of soil than 100% RD of NPK (control). Higher dose of FA recorded higher values of all the three nutrients. Integration of 100% RD of NPK with FA registered significant increase in available N, P and K content of soil over FA and control which decreased with the reduction in the dose of fertilizer. Treatments receiving FYM with 50% RD of NPK and FA recorded maximum N, P and K content among all the treatments and were comparable with integrated use of 100% RD of NPK with FA.

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